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STUDIES OF PLUM POLLEN, ITS APPEARANCE AND GERMINATION[1]

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INTRODUCTION

Among the varieties of plums grown in Texas the rate of pollen abortion, especially in interspecific hybrids, is often high. This aggravates the general plum pollination problem, which is already severe enough because of the usual condition of self-sterility and the frequent cross incompatibilities found in the native, Asiatic, and hybrid plums of the Southwest. It also complicates and retards improvement through breeding.

If the effort expended in a breeding program with plums grown in the Southwest is to prove most profitable, attention to several factors is essential. In addition to the more obvious of these, experience has shown that the pollen parent should have a fairly high percentage of normal pollen, and must furnish this in comparatively large amounts. Many of the hybrid varieties especially produce pollen that contains many small, misshapen, and otherwise deformed grains. While no data are presented here on the amounts of pollen produced by the different varieties, the results of a study now under way suggest that often a direct correlation exists between the amount of pollen produced and the percentage of it that appears normal. Experience in several seasons has shown that the use of pollen from parents that produce little viable pollen results in but few sets and seedlings even in crosses that appear genetically compatible. From the practical standpoint the use of such pollen parents is wasteful of time and effort and results in slow progress.

In the work reported here the primary points studied were (1) the percentages of normal pollen—as determined by microscopic appearance—for all the kinds of plums available, and (2) the germination percentages on nutrient agar of pollen of a number of representative varieties. Correlation coefficients indicating the association between the appearance and the actual germination of the pollen have been calculated. The present work has also considered certain factors possibly affecting the size of an adequate sample; whether the appearance and viability of pollen are affected by environmental factors; and whether pronounced pollen abortion is caused by hybridization. In several places genetic relationships are considered in connection with the appearance of the pollen and a knowledge of the origins of the various forms. Such discussions of probable genetic affinities are inferential, however, and direct proof is not attempted in this paper.

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[2] The writers acknowledge the assistance of Jack Brown in the securing of 1942 data.

EXPERIMENTAL PROCEDURE

MATERIALS

The plums from which pollen was available are listed in table 1. The 46 varieties include practically all the important commercial and home orchard varieties grown in Texas. A number of varieties seldom grown in the State are also included since they were being tested for adaptability or had potential value for the breeding program. In addition, the pollen of 14 *Prunus* species, and of a putative hybrid involving one of these, was examined. Most of these specific forms are plums; that is, most of them are placed botanically in sections Euprunus or Prunocerasus of subgenus Prunophora of *Prunus* (*20*).[3] Exceptions are *P. caroliniana* (the native cherry-laurel), *P. persica* (peach), and *P. serotina* (the native black cherry). *Prunus texana*, sometimes known as wild peach, is possibly another exception but this form is here treated with the Prunophora species.

TABLE 1.—*Percentage of normal pollen in the plum varieties and species studied* [1]

Variety or species	Specific origin of variety [2]	Location of form sampled [2]	Normal pollen		
			1940	1941	1942
			Percent	*Percent*	*Percent*
Abundance [4]	*S*	*C*	77.3		
Do		*ESO*		90.6	
Advance [5]	*S* × *Mu*	*C*	48.9		
Do		*ESO*		34.6	
Do		*GH*		38.9	
Allred	(?)	*ESO*	44.0	48.5	
America	*Mu* × *S*	*ESO*	31.0	40.6	
Do		*GH*		47.7	
Bartlett	*S* × *Si*	*C*	76.2		
Do		*ESO*		80.2	83.4
Bilona	*S* × *Me*	*ESO*		38.1	
Blue Damson	*I*	*ESO*		82.3	
Botan [4]	*S*	*GH*		90.8	
Bruce	*S* × *An*	*ESO*	25.1	25.7	34.4
Do		*GH*		32.0	
Do		*DHO*		25.6	
Do		*G*–1		33.8	
Bruce Jr	*S* × *An*	*C*	59.5		
Do		*ESO*		50.8	
Burbank	*S*	*C*	74.9		
Do		*ESO*		69.6	85.9
Do		*GH*		92.8	
Compass	*H Mi* × *B*	*ESO*	87.0	85.1	
Cumberland	*H*	*ESO*	85.7	80.9	87.8
Do		*GH*		81.1	
De Soto	*A*	*ESO*	79.7	84.6	
Diamond	*D*	*ESO*	71.0	64.5	
Doris	*C* × *An V*?	*C*	80.1		
Do		*ESO*		93.3	
Eagle	*An V*	*ESO*	81.3	90.3	84.8
Elephant Heart	(?)	*ESO*	94.4	95.3	87.6
Excelsior	*S* × *Mu*	*GH*	61.3	61.9	66.0
Gold [6]	*S* × *Mu*	*ESO*	37.3	35.9	
Do		*GH*		34.7	
Golden Beauty	*H*	*ESO*	70.8	90.7	
Do		*GH*		75.2	
Gonzales	*An V* × *S*?	*GH*	47.4	43.3	
Green Gage	*D*	*ESO*		54.0	
Happiness	*S* × *Mu*?	*DHO*		48.4	
Kelsey	*S*	*ESO*	47.4	61.7	
May Beauty	*S* × *A*	*ESO*		46.1	
Methley	*S* × *C*	*C*	56.4		
Do		*ESO*		64.9	49.5
Do		*DHO*		63.5	
Milton	*Mu* × ?	*C*	68.1		
Do		*ESO*		69.9	

See footnotes at end of table.

[3] Italic numbers in parentheses refer to Literature Cited, p. 357.

TABLE 1.—*Percentage of normal pollen in the plum varieties and species studied*—Continued

Variety or species	Specific origin of variety	Location of form sampled	Normal pollen		
			1940	1941	1942
			Percent	*Percent*	*Percent*
Munson [7]	$S \times (Mu \times S)$?	*C*	58.3		
Do		*ESO*		55.5	
Do		*GH*		57.7	
Do		*DHO*		63.6	
Nona	$S \times An\ V$	*GH*		36.2	49.0
Opata	$B \times (Mu \times S)$	*GH*	53.6	60.5	
Do		*ESO*		55.6	
Poole Pride	*Mu*	*C*	65.0		
Do		*ESO*		93.5	82.6
Do		*GH*		86.2	
Red June	*S*	*C*	67.2		
Do		*ESO*		82.0	
Santa Rosa	*S*	*ESO*		69.7	
Do		*GH*		69.4	
Do		*DHO*		77.7	
Sapa	$B \times S$	*GH*	91.9		
Do		*ESO*	87.1	85.5	
Satsuma	*S*	*ESO*		95.7	
Shiro	$(Si \times S) \times C \times Mu$	*DHO*		86.5	
Do		*ESO*			90.3
Six Weeks	$S \times AnV$	*GH*		41.9	
Do		*ESO*			40.3
Surprise	*H Mi*	*GH*	92.1	74.0	
Do		*ESO*		75.5	67.3
Terrell	$S \times Mu$	*GH*		57.9	72.3
"Uvalde" [8]	*S*	*C*	85.4		
Do		*ESO*		94.5	
Waneta	$S \times A$	*ESO*	48.9	45.5	
Wickson	$S \times Si$	*C*	93.7		
Do		*ESO*		84.3	94.2
Wild Goose	*Mu*	*ESO*	66.0	50.1	53.2
Do		*GH*		73.3	
Wright Early	*S*	*C*	91.9		
Do		*ESO*		86.8	
Yellow Iowa	(?)	*ESO*		49.4	
Prunus americana Marsh		*ESO*	89.5	96.3	
P. angustifolia Marsh					
Grapeland, Tex		*G-1*		92.2	93.4
Montague, Tex		*ESP*		98.8	
P. besseyi Bailey		*ESP*		95.8	89.2
P. bokhariensis Royle		*ESP*		78.5	
P. caroliniana (Mill.) Ait		*ESP*		95.9	94.7
P. gracilis Engelm. and Gray		*ESP*		81.3	
P. maritima Marsh		*ESP*		93.7	
P. mexicana S. Wats		*CC*	96.3	95.8	
Do		*NO*		93.4	
P. persica (L.) Batsch (Eclipse)		*ESO*			85.4
P. reverchonii Sarg		*ESP*		62.2	95.5
P. serotina Ehrh					88.6
P. simonii Carr		*ESO*	85.5	73.0	73.0
Do		*GH*		72.4	
P. texana Dietr		*Bex*		96.3	
P. texana hyb. No. 2		*GH*	88.6	93.5	
Prunus sp		*ESP*		95.5	

[1] Based on samples of approximately 1,000 grains each.

[2] Key to species abbreviations:
A=*Prunus americana*
An=*P. angustifolia*
An V=*P. angustifolia varians* Wight and Hedr.
B=*P. besseyi*
C=*P. cerasifera* Ehrh.
D=*P. domestica* L.
H=*P. hortulana* Bailey.
H Mi=*P. hortulana mineri* Bailey.
I=*P. insititia* L.
Me=*P. mexicana*
Mu=*P. munsoniana* Wight and Hedr.
S=*P. salicina* Lindl.
Si=*P. simonii*.
?=Species unknown or the given derivation is uncertain for form studied.

[3] Key to location of trees sampled: *Bex*=Bexar County, Tex.; *C*=cuttings from experiment station orchard which were brought to greenhouse in dormant condition and there forced into bud; *CC*=Cartel's Creek, Brazos County, Tex.; *DHO*=Department of horticulture orchard; *ESO*=experiment station orchard; *ESP*=experiment station plantings; *GH*=greenhouse; *G-1*=near Grapeland, Tex.; *NO*=North Oakwood addition, Bryan, Tex.

[4] Abundance and Botan are probably synonymous.

[5] This is the Advance variety introduced by F. T. Ramsey in 1908.

[6] The Gold variety used here is similar to the one first called Golden by Burbank and renamed Gold by Stark Bros.

[7] Not the same as Onderdonk's Munson which originated from *P. angustifolia varians*.

[8] A seedling of Satsuma which originated at Uvalde, Tex.; for convenience called in this paper "Uvalde."

The material used in the present studies has been carefully compared with published descriptions of the different varieties, and Cullinan (*6*), Hedrick et al. (*16*), Waugh (*27*), or Wight (*28*) have been accepted as authorities for the parentage given in table 1 for the varieties and species shown. Where these authorities disagree on varietal parentage, and the writers' own knowledge of the variety or species has not cleared up the point, the parentage is indicated as questionable. Where parental origins seem only fairly certain the varieties concerned are also marked as questionable. Nevertheless, the data from some of these are used in table 11. If no information on varietal parentage has been given by the authors cited this fact is indicated in table 1 by a question mark. The writers' observations and studies suggest the probable parentage in several of these questionable cases. Allred almost certainly had *Prunus cerasifera pissardii* for one parent with *P. salicina* perhaps as the other. Elephant Heart has several characters of the varieties of *P. salicina* × *P. simonii* origin. Characters of Milton suggest *P. simonii* as one of its parents. Yellow Iowa has all the characteristics of a hybrid between *P. salicina* and one of the American species, probably *P. angustifolia*.

The parental species of these varieties may be divided into three main groups, the native American species (*Prunus americana*, *P. angustifolia*, *P. besseyi*, *P. hortulana*, and *P. munsoniana*), the Oriental species (*P. salicina* and *P. simonii*), and the European or western Asiatic species (*P. domestica*, *P. insititia*, and *P. cerasifera*). Most of the species just named are known diploids with 16 somatic chromosomes (*8*, *9*, *14*, *22*), but *P. domestica* and *P. insititia* are hexaploids with 48 chromosomes (*5*). No recorded chromosome number has been found for *P. besseyi*, but the crossing behavior and hybrid progeny fertility of this form indicate it to be a diploid. Parental chromosome number differences apparently have not contributed to any pollen abortion reported herein since neither *P. domestica* nor *P. insititia* are involved in any of the hybrid varieties used in this study. Of the botanical species listed only *P. caroliniana* is known to be other than diploid; it is a tetraploid with 32 somatic chromosomes (*14*).

Of the varieties studied 40 grew outdoors in the experiment station orchard (*ESO*), 20 were grown in tubs in the greenhouse (*GH*), 15 were grown at both of these locations, 6 were grown in the Department of Horticulture orchard [4] (*DHO*), and a few in other places. Most of the botanical species were in experiment station plantings (*ESP*), though a few were in other locations as noted in table 1. Some importance was attached to the location of the trees, as will be shown later, because of the possible effects of different environments on pollen viability.

METHODS

Pollen was collected in the same manner as in the breeding program; in fact, many of the samples were taken from vials of pollen which were later used in pollinating work. Because of the nature of the material it was necessary that the varietal pollen collections be secured from relatively large numbers of buds. In most instances the number ranged from a minimum of 100 to several hundred, and in a few instances, to many hundreds. To secure so many buds in

[4] The writers are indebted to Dr. Guy W. Adriance, head of the Department of Horticulture, Texas Agricultural and Mechanical College, for the use of material from this orchard.

the proper stage of development they had to be picked from many different branches and positions on the tree. No counts were made of the number of flowers used from the varieties from which pollen was secured specifically for the viability work, but in most such cases, anthers were taken from approximately 50 buds, from various places on the tree. From some varieties, however, only a few buds were available. Most, but not all, of the percentages recorded in table 1, therefore, were based on samples taken from bud and pollen collections that would be considered relatively large for this material. Where the term "relatively large pollen collection," or its equivalent is used hereafter in this paper it refers to pollen collections secured from at least 50, and in most cases many more, buds picked at random from various positions on a tree.

Buds were gathered just before anthesis and the anthers were stripped into flat glass containers for drying and dehiscence. After dehiscence anthers and pollen were collected in vials. When the pollen was not to be used at once the uncorked vials were stored, according to the method of Nebel and Ruttle (*18*), at approximately 50 percent relative humidity and 41° F. temperature.

The extent of normal pollen in the various forms was determined in 1940, 1941, and 1942 from mounts in acetic acid which contained a small quantity of iodine. Plump, regular appearing grains that were filled with cytoplasm were counted as normal. The cytoplasm in these was always stained to some extent, but there was considerable variation from light to dark in the grains that were considered as normal. It was thought that maturity of the grains with the consequent differences in thickness or permeability of the cell wall, as well as differences in the carbohydrate make-up of the cytoplasm, might influence the depth of stain, but there is no proof that this surmise is correct. In this paper the term "normal" is used as the antonym of "aborted," and vice versa. Occasionally "apparently good pollen" is used synonymously with "normal pollen." Both terms as used in this paper refer to appearance and not to viability. Empty or shriveled grains, as well as those obviously below normal in size, were counted as aborted for purposes of this study. It is to this obvious condition only that the term abortion here refers. The sample size was set arbitrarily at 1,000 grains, but in some cases as many as 1,100, 1,200, or even 1,300 grains were counted. Mounts were manipulated by a mechanical stage so as to avoid duplicate counts and insure random sampling. Mechanical hand tallies were used in taking the counts, all of which were made at a magnification of 200 diameters.

The medium used for all germination counts recorded here consisted of the following: 100 cc. of distilled water, 20 gm. sucrose, 1.5 gm. shredded agar, and 8 drops of sterile yeast extract. Recommendations of several workers (*1*, *2*, *3*, *21*) for the artificial culture of pollen were adopted as the basis for a series of preliminary nutrient formulas, from which evolved the one finally used. A number of workers (*1*, *21*, and others) have pointed out that the optimum medium varies, especially with respect to the percentage of cane sugar contained, from species to species. Since at least eight different species, and an even greater number of interspecific combinations, are involved in the present studies, it is not to be expected that the single nutrient formula fol-

lowed gave an optimum germinating medium for all the species and varieties used.

Germination tests were made both in 1941 and 1942. In 1941 all tests were run as soon as possible after pollen collection, on slide plates carried in sterile Petri dishes. One thousand-grain samples were used for each variety, but these were made up of about one-third that many grains from each of three replicated cultures. In 1942 some tests were made with pollen that had been stored for a short time, and it seems probable that germination percentages may have been lowered in some cases because of this. The 1942 cultures were on slides carried in horizontal staining dishes. Samples of only about 300 grains were counted. Final counts on germinating pollen grains were made approximately 24 hours after the cultures were started.

STUDIES OF NORMAL AND ABORTED POLLEN BASED ON MICROSCOPIC APPEARANCE

FACTORS AFFECTING ADEQUACY OF SAMPLE

A number of workers dealing with pollen abortion have expressed percentages without stating the number of grains counted (*4*, *7*, *21*, *24*). Becker (2) counted 3,000 to 8,000 grains for most plum hybrids examined, but only 400 and 500 in certain cases. Dorsey (*10*) based his percentages in grape pollen on 200 grains of each variety, and in plum pollen (*11*) on less than 300 grains of each in most cases, although more were counted in some forms. Valleau (*25*) calculated pollen abortion percentages in strawberries on counts of from 200 to 2,000 grains. Apparently it was felt by these investigators that enough grains were included in the counts to indicate within a close range the percentage of abortion, but no mention is made of estimating this by statistical tests in any of the papers referred to.

As was stated earlier, in the present work the sample size was set arbitrarily at about a thousand grains. It seemed reasonably safe to assume—from early observations as well as from the work of others—that this number was sufficient for a reliable sample. The general year-to-year similarity of pollen from the same varieties (table 1) apparently supports this assumption. There are, however, a few year-to-year and source-to-source variations in amounts of normal pollen, that offer exceptions to the general trend of the data. These occasional discrepancies, together with certain observations reported by others, have made it seem important to give especial attention to the factors which affect the size of an adequate sample.

The mechanics of collecting, mixing, and sampling pollen could possibly have a bearing on this question. The writers' usual method of collecting and mixing pollen from many flowers for a varietal sample, appeared to represent a good approach, usually reliable statistically, for general varietal indications from a relatively small total count. Yet there is sometimes a question as to the adequacy of the mixture. Plum pollen is difficult to separate from the anthers without a costly loss of pollen. Consequently, as mentioned earlier the vials contained not only pollen but also the anthers from which it dehisced. There is a decided tendency for pollen, especially of some varieties, to remain in, or in contact with, the anther after dehiscence even following through drying.

It is obvious that if there should be differences in pollen abortion between flowers on the same tree certain procedures could influence the percentages purported to represent the amount of good pollen in any particular variety. The discussion and the description of the study given below present the information available on this point.

Valleau (*25*) found flower-to-flower variations on single strawberry plants. Five flowers from one seedling had from 9.9 to 25.5 percent of aborted pollen. In another seedling pollen was counted in each flower of two different inflorescences on different stalks. In one stalk the percentage range of pollen abortion was from 31.1 to 91.1, in the other inflorescence it was from 21.4 to 40.3. Valleau carried the study a step further and found the percentage of abortion to vary from 17.09 to 50 in the nine different anthers of a single flower. Smith (*23*) also noted some anther-to-anther pollen variation in the same flower of certain species.

The following experiment was carried out to determine what differences, if any, might exist between flowers on the same plum tree. Pollen was collected separately from 20 different flowers from 2 clusters on separate branches of a tree of the variety Surprise, and abortion counts were made. Table 2 records these counts. The range in percentage of normal pollen is from 54.5 to 96.7, and the chi-square value (χ^2=1,697.775, degrees of freedom=19) leaves no doubt of the heterogeneity of the samples.

TABLE 2.—*Normal and aborted pollen in different flowers on the same Surprise plum tree*

Flower No.[1]	Pollen grains counted			Percent normal [2]
	Normal	Aborted	Total	
	Number	*Number*	*Number*	
1	901	111	1,012	89.0
2	978	33	1,011	96.7
3	828	372	1,200	69.0
4	920	235	1,155	79.7
5	764	289	1,053	72.6
6	944	108	1,052	89.7
7	701	418	1,119	62.6
8	866	154	1,020	84.9
9	602	432	1,034	58.2
10	991	101	1,092	90.8
11	791	252	1,043	75.8
12	719	317	1,036	69.4
13	813	248	1,061	76.6
14	885	120	1,005	88.1
15	829	308	1,137	72.9
16	601	417	1,018	59.0
17	723	300	1,023	70.7
18	575	481	1,056	54.5
19	613	393	1,006	60.9
20	917	113	1,030	89.0
Total or average	15,961	5,202	21,163	75.5

[1] Flowers 1 to 10 were obtained from a cluster on one branch of the tree and flowers 11 to 20 from a cluster on a different branch.
[2] χ^2=1,697.775**, Degrees of freedom=19.
**=Significant at the 1-percent level.

This seemed to raise the question whether an adequate varietal sample could be obtained from a small number of flowers, and led to the analysis of some combined data from table 2. By combining counts from flowers 1 to 5, 6 to 10, 11 to 15, and 16 to 20, of this table,

and calculating the chi-square value on these samples of more than 5,000 grains each, we find these too to be heterogenous ($\chi^2=303.818$, d. f.=3). When flower numbers 1 to 10 and 11 to 20 are combined to give 2 samples of 10,000 grains each, they still deviate significantly (table 3).

It is evident that marked pollen variation occurred in individual flowers and also in individual clusters of flowers from different positions on the tree. Consequently, when samples from a small number of individual plum flowers are combined in this manner it is probable that usually a relatively enormous total number of grains would be necessary to furnish an adequate varietal sample. But in the light of experiments to be described later (see table 5), these data cannot be construed as showing that such large numbers of grains are needed for an adequate sample of a variety where, as with most of the writers' material, pollen collections are comprised of anthers from many flowers well mixed in a single vial.

TABLE 3.—*Normal and aborted pollen of flowers 1 to 10 and 11 to 20 of table 2 combined to give 2 samples of 10,000 grains each*

Flower Nos.	Pollen grains counted			Percent [1] normal
	Normal	Aborted	Total	
	Number	*Number*	*Number*	
1–10	8,495	2,253	10,748	79.0
11–20	7,466	2,949	10,415	71.7
Total or average	15,961	5,202	21,163	75.4

[1] $\chi^2=154.261^{**}$ degrees of freedom = 1.
**=Significant at the 1-percent level.

An abstract of a paper by Wanscher (*26*), which has just come to hand, seems to present results bearing closely on the flower to flower variations just discussed. Wanscher determined the percentages of stainable pollen in 12 different varieties of peach (*Prunus persica*). He states:

> As a rule the percentages of stainable grains were highest at the base of the twigs, the values being gradually lower and usually reaching 0 at their tips. E.g., a short twig, 5 cm. long and with . . . 4 . . . flower buds, showed the following values, the proximal bud being mentioned first: 75%, 5%, 9% and 0% of good pollen.

Wanscher further concluded:

> Pollen quality, as measured by percentages of stainable grains, depends on the physiology of the flower producing the pollen . . .

The paper by Wanscher came to the writers' attention after the 1942 blooms were past and consequently too late to test, during the past season, the effect of flower position on pollen abortion in plums. Since there is such positional effect in the peach it might logically be expected in other species of *Prunus*. The writers' results with pollen from the different flowers of Surprise plum do suggest that here, also, flower position may have an effect on the pollen.

To study further the effect of size of sample, and also size of the pollen collection being sampled, on the reliability of the abortion

percentages obtained, counts were made on several samples from single collections of two different plum varieties.

Counts were first made on seven samples taken from a vial containing a small collection of pollen from a single tree of the Bruce variety. The counts are recorded in table 4. Again the highly significant value of chi square (χ^2=18.712, d.f.=6) would indicate that these samples were not drawn from a homogenous population. The size of the collection, however, makes it questionable whether this sample adequately represents the tree from which it was obtained.

TABLE 4.—*Variation in samples of pollen from a single tree of Bruce plum* [1]

Sample No.	Pollen grains counted			Percent normal [2]
	Normal	Aborted	Total	
	Number	*Number*	*Number*	
1	238	777	1,015	23.4
2	314	767	1,081	29.0
3	304	729	1,033	29.4
4	327	798	1,125	29.1
5	260	793	1,053	24.7
6	273	798	1,071	25.5
7	299	778	1,077	27.8
Total or average	2,015	5,440	7,455	27.0

[1] All samples from a small pollen collection carried in a single vial.
[2] χ^2=18.712**, degrees of freedom=6.
**=Significant at the 1-percent level.

In the second case a relatively large pollen collection, obtained from the anthers of several hundred flowers, was available from a single Burbank tree. Particular attention was paid to mixing the collection thoroughly before sampling. Results from the 10 samples counted here are given in table 5. The chi-square value (χ^2=15.116, d.f.=9) is not statistically significant and indicates, of course, that the 10 samples were derived from a homogenous population. The results of tables 4 and 5 clearly show the importance of deriving tree or varietal pollen samples from sufficiently large and well-mixed collections of flowers and pollen.

TABLE 5.—*Variations in samples of pollen from a single tree of Burbank plum* [1]

Sample No.	Pollen grains counted			Percent normal [2]
	Normal	Aborted	Total	
	Number	*Number*	*Number*	
1	928	81	1,009	92.0
2	936	76	1,012	92.5
3	917	112	1,029	89.1
4	942	79	1,021	92.3
5	1,011	85	1,096	92.2
6	951	76	1,027	92.6
7	946	91	1,037	92.2
8	932	82	1,014	91.9
9	1,028	90	1,118	91.9
10	986	74	1,060	93.0
Total or average	9,577	846	10,423	91.9

[1] All samples from a large well-mixed pollen collection carried in one vial.
[2] χ^2=15.116, degrees of freedom=9.

This section may be summarized and several conclusions presented as follows: There is a flower-to-flower variation in the amount of normal pollen in Surprise and, presumably, in other plum varieties. Such variations are most apt to be apparent, because of the probabilities involved, in small and in poorly mixed pollen collections. Such collections, therefore, cannot be relied upon to furnish reliable pollen indexes. Finally, the evidence does not make it seem unsafe to conclude that in most cases 1,000-grain samples, taken from the well-mixed pollen furnished by many flowers, are sufficiently large to give a reliable varietal index.

PERCENTAGE OF NORMAL POLLEN IN DIFFERENT VARIETIES AND SPECIES

Table 1 shows the percentages of normal pollen for the different plum varieties and *Prunus* species examined. These vary from about 25 percent for Bruce to almost 100 percent for a number of species and also for some varieties derived from single species. A brief summary of the number of forms studied each year is given in table 6. The average percentages of normal pollen given here have little significance as such. They are interesting chiefly because they indicate the mean values and also because of their similarity from year to year.

TABLE 6.—*Summary by years of the number of forms studied with the average percentages of normal pollen observed*

Year	Forms studied			Average normal pollen	
	Varieties	Species	Total	Varieties	Species
	Number	*Number*	*Number*	*Percent*	*Percent*
1940	33	4	37	67.2	90.0
1941	46	13	59	67.2	88.6
1942	16	7	23	70.5	88.5

TABLE 7.—*Comparison of the proportion of normal pollen produced by the same varieties during different seasons*

Years	Number of varieties	*r*
1940–41	37	0.872**
1940–42	13	.807**
1941–42	21	.853**

**=Significant at the 1-percent level.

Pollen from several varieties was examined in more than 1 year. Thirty-seven forms were studied both in 1940 and 1941, 13 in 1940 and also in 1942, and 21 in 1941 and again in 1942. Close examination of table 1 shows rather uniformly consistent results from year to year although some discrepancies do occur. Where varieties were studied in more than one season the percentages of normal pollen were compared, in tabular form, for each variety examined in the 2 years concerned. The paired percentages were deliberately taken for pollen of trees from different sources whenever possible. Correlation coefficients were than determined for percentages of normal pollen of all varieties, as a whole, examined in each of the same 2 years. The calculated correlation coefficients (r) are given in table 7. These are

all highly significant and indicate that there is a strong tendency for the percentage of normal pollen from a given variety to be consistent from year to year, and this in spite of the source. Varieties low in such percentages one year tend to be low in other years and, in like manner, those that are high tend to remain high. To this extent, then, the rate of pollen abortion is a varietal characteristic, and hence presumably dependent chiefly upon the genotype of the variety.

EFFECT OF ENVIRONMENT ON THE PROPORTION OF NORMAL POLLEN

The effect of environment on the viability of pollen has been studied in a number of plants. Sandsten (*21*), working on cultured pollen of several forms, found that the average percentage germination of pollen of *Prunus americana* and of *P. domestica* was unaffected by sunshine or cloudiness; and also that the vitality of plum and certain other pollens is not seriously affected by temperatures ranging from 25° to 55° C. in dry atmosphere, but that higher or lower temperatures are apt to interfere with germination. In apples Sandsten found that pollen from trees in a neglected orchard germinated poorly as compared with that from trees on similar soil in an adjacent well-fertilized, well-sprayed, and well-cared-for orchard. Poole (*19*) concluded from his studies with *Crepis* species and hybrids that the percentage of pollen abortion is little if at all influenced by certain external factors, such as temperature, but is somewhat dependent upon the time in the flowering or physiological cycle at which pollen is collected. Edmundson (*12*), working with Katahdin potato pollen in Colorado, found that a higher percentage of stainable pollen was produced in the greenhouse than in the field at Greeley; also that a higher percentage of stainable pollen was produced in the field at Estes Park than in the field at Greeley. He concluded, however, that the differences were not large enough to influence fertilization and seed production.

That there is a varietal tendency toward year-to-year consistency in proportions of plum pollen that are normal in appearance has already been shown (table 7). To further check the seasonal effect a year-to-year comparison may be made of varieties from a single source. From table 1 it may be seen that pollen from 17 varieties and species was secured and studied in both 1940 and 1941 from trees growing in the experiment station orchard. These forms were Allred, America, Bruce, Compass, Cumberland, De Soto, Diamond, Eagle, Elephant Heart, Gold, Golden Beauty, Kelsey, Sapa, Waneta, Wild Goose, *Prunus americana*, and *P. simonii*. As might be expected, the calculated correlation coefficient ($r=0.919$, d.f.$=15$) is highly significant, indicating again that the same varieties respond similarly from year to year. The t value ($t=1.378$, d.f.$=16$) for this comparison, which is not significant, gives additional evidence of the similarity of response from year to year. The variation which does occur (both here and in the two following comparisons) is evidently due to sampling, since the positive and negative deviations for the 2 years tend to compensate, and hence are not due to seasonal effect. For the varieties used the data from 1940 and 1941 might have been from the same population in the same year. The indication is, therefore, that there is no general seasonal trend when all varieties are considered together.

In 1940 branches of a number of varieties in the experiment station orchard were cut several weeks before the orchard trees bloomed. These, when placed in water in a warm greenhouse, were forced into bloom and then used as pollen sources. Again referring to data in table 1 it may be seen that pollen of 14 of these varieties was secured in 1941 from the same orchard but from the trees as they bloomed naturally. These varieties were Abundance, Advance, Bartlett, Bruce Jr., Burbank, Doris, Methley, Milton, Munson, Poole Pride, Red June, "Uvalde", Wickson, and Wright Early. In this case a chance is given to compare pollen of the same varieties in different years, but from buds which opened under quite different environmental conditions. The correlation coefficient ($r=0.763$, d.f.$=12$) is highly significant, again suggesting that the same varieties tend to respond similarly, even when their buds develop in markedly different environments. Further, when the percentage of normal pollen from the 1940 forced cuttings is compared with that from orchard trees in 1941 the t value ($t=1.073$, d.f.$=13$) signifies that there is no significant difference. Examination of the data indicates some individual exceptions especially with Poole Pride, and to a lesser extent with Red June, Advance and Abundance.

A comparison can also be made between the proportions of normal pollen of varieties grown under quite different conditions and environments. In 1941 the pollen of 14 varieties grown both in the experiment station orchard and in the greenhouse was studied. The orchard soil is a deep Norfolk fine sand. The trees in the greenhouse were grown in tubs with a soil mixture of two-fifths Lufkin fine sandy loam, two-fifths Susquehanna fine sandy loam, and one-fifth composted manure and peat moss. In addition to the soil differences there were decided differences in temperature, humidity, and perhaps other environmental factors. The varieties used for this comparison were Advance, America, Bruce, Burbank, Cumberland, Gold, Golden Beauty, Munson, Opata, Poole Pride, Santa Rosa, Surprise, Wild Goose, and Simon (*P. simonii*) (table 1). When the varieties are grouped together the highly significant correlation coefficient ($r=0.879$, d.f.$=12$) and the nonsignificant t value ($t=1.173$, d.f.$=13$) lead to the conclusion that the effect of this type of environment on the amount of pollen developed is similar in degree to that for seasonal influence. At least there is no general over-all effect. It may be noted, however, that rather large discrepancies were found in the counts on Burbank, Golden Beauty and Wild Goose at the different locations. It is possible, though it does not seem probable when all the data are considered, that such discrepancies may represent real differences due to environment for certain varieties. It seems more likely to the writers that discrepancies such as these, and also those noted in the preceding paragraph, can be attributed to the smallness of certain of the pollen collections, or to some similar sampling effect (compare with the section on factors affecting adequacy of sample).

By way of summarizing the closely connected studies of this and the two preceding sections it may be pointed out that the various counts show that pollen of any given variety remains at a surprisingly consistent level under varying conditions. In most cases 1,000-grain samples secured from the carefully mixed pollen of many flowers appear sufficiently large to give a reliable index for a variety. The few discrepancies noted in year-to-year and place-to-place comparisons

of pollen samples, as well as those between samples from the same tree, are probably explainable by the, presumably physiological, variation observed among small samples from flowers on the same tree.

DERIVATIVES OF SINGLE SPECIES COMPARED WITH INTERSPECIFIC HYBRIDS

From table 1 it may be noted that the varieties available for study were rather evenly divided between those that have been derived directly from single species and those that have originated from interspecific hybridization. A summarized comparison of the normal pollen in all observed forms from each of these methods of derivation is presented in table 8. It is evident that the hybrids as a group have a lower percentage of nonaborted pollen than have the forms which represent single species. In general, the pure species and their derived varieties averaged close to 80 percent of normal pollen, which is roughly 20 points higher than the approximate 60 percent average of the hybrid varieties. These approximate percentages were consistent for each of the 3 years covered by the study.

A better picture of the varying percentages found between hybrids and pure species, as groups, may be obtained from the frequency distribution, according to classes, in table 9. This table shows that

TABLE 8.—*A summary comparison of percentages of normal pollen in plums derived from single species and in hybrid plums involving at least 2 species*

Derivation	1940		1941		1942	
	Forms studied	Average normal pollen	Forms studied	Average normal pollen	Forms studied	Average normal pollen
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Single species (Prunophora)	17	78.1	29	82.4	10	81.3
Single species (not Prunophora)			1	95.9	3	89.6
Interspecific hybrids	16	59.6	23	57.0	9	64.4
Unknown	3	68.8	4	65.7	1	87.6

TABLE 9.—*Frequency distribution of hybrid and single species of plums with reference to percentage of normal pollen*

Classes (percent of normal pollen)	Frequency distribution								
	1940			1941			1942		
	Hybrids		Single species	Hybrids		Single species	Hybrids		Single species
	Distantly related parents [1]	Closely related parents [2]		Distantly related parents [1]	Closely related parents [2]		Distantly related parents [1]	Closely related parents [2]	
25–29.9	1			1					
30–34.9	1						1		
35–39.9	1			4					
40–44.9				3			1		
45–49.9	3		1	3			2		
50–54.9	1			1		1			1
55–59.9	3			3					
60–64.9	1			2		4			
65–69.9			3				1		1
70–74.9			3			3	1		1
75–79.9		1	2			1			
80–84.9		1	1		2	7		1	2
85–89.9		2	4		3	2			5
90–94.9		1	2		1	6		2	2
95–99.9			1			6			1

[1] With the exception of Methley these were hybrids between *Prunus salicina* and 1 of the American species (but not *P. besseyi*).

[2] Hybrids between 2 Asiatic species, 2 American species, or hybrids involving either *P. besseyi* or *P. cerasifera* with either American species or *P. salicina*.

a decided preponderance of the specific forms have a percentage of normal pollen exceeding 65 (16 of 17 varieties in 1940, 25 of 30 in 1941, and 12 of 13 forms in 1942 were above this mark). On the other hand, the majority of the hybrid varieties had less than 65 percent of normal pollen in 1940 (11 of 16 hybrid varieties) and 1941 (17 of 23 such varieties). In 1942, with a smaller number of kinds involved, two-thirds of the hybrids had less than 75 percent of apparently good pollen.

The percentage of normal pollen exhibited by the specific plums ranged from about 50 to almost 100 with only one variety falling under 60 in each year. For hybrids the total range was consistently greater, running from about 25 or 30 to 95. The hybrid varieties, however, have been broken down into two groups, shown in table 9 in two columns for each year, i. e., those developed from parents that are apparently distantly related, and those developed from presumably more closely related parents. The great majority of the hybrids with less than 65 percent of normal pollen belong to the former group. The hybrid varieties which exceeded 65 percent of apparently good pollen in 1940 and 1941 included Bartlett, Compass, Doris, Sapa, and Wickson in both years, and Shiro in 1941. Those exceeding 75 percent of apparently good pollen in 1942 were three of these same varieties, Bartlett, Shiro, and Wickson. It is partly due to the higher levels of normal pollen found in these particular varieties that a rather close relationship is thought to exist between the parents involved. This point is discussed in greater detail in later paragraphs.

The percentage of normal pollen in different species, and in the varieties which have been derived directly from species, is shown in table 10. The three subtotals present summary data for all the American, all the Asiatic, and all the European species studied. These indicate that the American plums have, on the whole, slightly the best pollen of the three groups, the percentage of apparently good pollen being somewhat above 80. The Asiatic derivatives have somewhat less normal pollen than the American. The few European varieties studied averaged only about 70 percent of normal pollen. There are several reasons which, separately or combined, might explain the greater abortion rate observed in pollen of the European plums, assuming first that the small number of varieties permits a fair sample. In the first place European plum varieties are not well adapted to the Southwest. Possibly the same environmental factors that result in scant flowering, low fruit production, and short-lived trees also cause a reduction in the amount of normal pollen. If this is the case the types of environment that would probably be involved would be much wider in range than those checked in the present work. There are other possible influencing factors, however. It may be noted from the summary at the end of table 10 that domesticated varieties in general have slightly less normal pollen than do the wild specific forms; the European plums sampled were all domesticated varieties, while botanical species are included in the other two continental groups. Further, according to Hedrick (*15*) and others, it seems likely that the European varieties have been grown under domestication for a longer period than the plums from other regions. Such length of removal from indigenous conditions might possibly involve genetic changes affecting chromosome pairing and hence fertility in general and, in the present case, the appearance of pollen in particular. A

further factor having a possible bearing here is the hexaploid condition of the European plums as contrasted with the diploid chromosome complements of the other plums studied.

TABLE 10.—*Percentage of normal pollen (1) in varieties originating from single species and (2) in botanical species of Prunus*

Botanical species studied, or from which varieties studied originated	1940		1941		1942	
	Forms studied	Average, normal pollen	Forms studied	Average normal pollen	Forms studied	Average normal pollen
American species:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
P. americana						
Variety	1	79.7	1	84.6		
Species	1	89.5	1	96.3		
P. angustifolia						
Variety	1	81.3	1	90.3	1	84.3
Species			1	95.5	1	93.4
P. besseyi						
Species			1	95.8	1	89.2
P. caroliniana						
Species			1	95.9	1	94.7
P. gracilis						
Species			1	81.3		
P. hortulana						
Varieties	3	82.9	3	79.5	2	77.5
P. maritima						
Species			1	93.7		
P. mexicana						
Species	1	96.3	1	94.6		
P. munsoniana						
Varieties	2	65.5	2	75.7	2	67.9
P. reverchonii						
Species			1	62.2	1	95.5
P. serotina						
Species					1	88.6
P. texana						
Species			1	96.3		
Total, or average American species	9	80.7	16	86.0	10	83.7
Asiatic species:						
P. bokhariensis						
Species			1	78.5		
P. persica						
Species					1	85.4
P. salicina						
Varieties	6	74.0	9	84.0	1	85.9
P. simonii						
Species	1	85.5	1	72.6	1	73.0
Total, or average Asiatic species	7	75.6	11	82.5	3	81.4
European species:[1]						
P. domestica						
Varieties	1	71.0	2	59.2		
P. insititia						
Variety			1	82.3		
Total, or average European species	1	71.0	3	66.9		
Summary:						
Varieties from single species	14	75.4	19	80.1	6	76.9
Specific forms	3	90.4	11	87.5	7	88.5

[1] These 2 species are sometimes (*20*) said to be natives of Europe and western Asia. They are listed here as European, however, in order to more readily distinguish them from the more eastern and entirely Asiatic species.

In table 11, in which the percentages of normal pollen in hybrid varieties is considered, the varieties are arranged in five groups on the basis of the relationship of the parents involved. Only one variety, Compass, is a hybrid between two native American species. Two varieties, Bartlett and Wickson, are hybrids between the eastern

Asiatic species *P. salicina* and *P. simonii*. These constitute the first two groups of table 11. It will be seen that each of these groups is characterized by well over 80 percent of good appearing pollen.

The third group includes hybrids of five American species with the Japanese plum. Percentages of nonaborted pollen range in general around 50, or lower. There is one notable exception—the *P. besseyi* × *P. salicina* derivative, Sapa. This has pollen much superior to that of the other varieties of this group.

In the fourth group are Methley (*P. salicina* × *P. cerasifera*) with mediocre looking pollen, 50 percent or somewhat more of which is apparently nonaborted, and Doris (*P. cerasifera* × *P. angustifolia varians*—?) which has much normal pollen.

The last group is a miscellaneous one including the remaining forms, the complex hybrids in which three or more species are numbered among their antecedents. Two of these have mediocre and the third excellent appearing pollen.

TABLE 11.—*Percentages of normal pollen in hybrid plum varieties*

Parentage of varieties studied [1]	1940		1941		1942	
	Forms studied	Average normal pollen	Forms studied	Average normal pollen	Forms studied	Average normal pollen
American interspecific hybrid:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
P. hortulana mineri × *P. besseyi*	1	87.0	1	85.1		
Asiatic interspecific hybrid:						
P. salicina × *P. simonii*	2	84.5	2	82.2	2	88.8
Asiatic-American hybrids:						
P. besseyi × *P. salicina*	1	89.5	1	85.5		
P. salicina:						
× *P. americana*	1	48.9	2	45.8		
× *P. angustifolia*	3	44.0	5	40.3	3	41.2
× *P. mexicana*			1	38.1		
× *P. munsoniana*	4	44.6	6	47.4	2	69.1
Total	9	49.9	15	46.8	5	52.4
Hybrids with *P. cerasifera:*						
P. salicina × *P. cerasifera*	1	56.4	1	64.2	1	49.5
P. cerasifera × *P. angustifolia varians*	1	80.1	1	93.3		
Complex hybrids:						
P. besseyi × (*P. munsoniana* × *P. salicina*)	1	53.6	1	58.0		
P. salicina × (*P. munsoniana* × *P. salicina*)	1	58.3	1	58.9		
(*P. simonii* × *P. salicina*) × *P. cerasifera* × *P. munsoniana*			1	86.5	1	90.3

[1] Seed parents are uncertain in some cases and some crosses may have been the reciprocals of those indicated.

It seems likely that in plums, as in other plants, the extent of interspecific hybridization plays an important role in pollen abortion, and that there is here a direct correlation between the general level of nonaborted pollen in hybrids and parental relationships. The American species may be assumed to be much more closely related to each other than to the Asiatic species, and likewise the affinities between the Asiatic species would logically be greater than between these and the American species. Consequently it is not unexpected to find the hybrids between American species, and also those between the eastern Asiatic species, with about as much normal pollen as the parental

forms from which they originated (table 10). In contrast to this the Asiatic × American hybrids for the most part have much aborted pollen which is presumably one expression of the more distant relationship existing between the species of two continents. The high percentage of normal pollen exhibited by the *P. besseyi* × *P. salicina* hybrid would indicate less genetic difference between these species than between the Japanese and the other American forms. The percentages of apparently good pollen observed in the two forms of the fourth group, both of which contain *P. cerasifera* genes, would suggest that this western Asiatic species might be genetically closer to the American *P. angustifolia* (probably the other parent of Doris) than to the Japanese *P. salicina*. Conclusions in line with the ones made above might also be drawn for the parental species of the complex hybrids in the last group.

POLLEN GERMINATION

Pollen germination tests were made on 21 different varieties in 1941 and on 18 varieties in 1942. The results are recorded in table 12. Germination tests were usually made soon after collection (see Methods) with pollen from the same vial from which the abortion counts were made. It is to be noted that, as was to be expected, the percentages of actual germination are markedly lower in each case than are those for apparently good grains.

Considerable variability was found in pollen germination of the same varieties: (1) On different plates of pollen from the same source in 1941; (2) in tests with pollen from different sources—as note the results with Cumberland and Santa Rosa in 1941 (table 12); and (3) in different years. Similar variability has been observed by other workers making pollen germinations and, accordingly, was not unexpected. Brink (*3, p. 225*) states that "the seemingly inordinate variability sometimes encountered should not be permitted to abscure the results of experiments where regularity does prevail" and he further suggests that such variations cannot be ascribed entirely to basic differences in the material "but rather to its somewhat capricious nature, resulting in fluctuations of a minor sort which an imperfectly developed technic fails to set forth in true perspective." Nebel and Ruttle's (*18, p. 349*) simple observation that "Germination on the microscope slide is at times erratic for unknown reasons" seems to be a concise statement covering the writers' own as well as other cases.

The divergent results with the pollen of Cumberland, and also of Santa Rosa, might be explained by the fact that the two germination tests with each were made at different times and at laboratory temperatures. Thus it is possible that external factors at the time of making the tests caused some of the variation. It has been shown by others that the germination of plum pollen is affected by such factors as the kind of weather that prevails during the blooming season (*17*) and by changes in temperature (*2*). Similar causes could account for some of the variation between seasons. Apparently, however, no environmental differences occurred to cause the plate-to-plate, or sampling, differences found within the same variety. It is probable that here, too, the size of the pollen collection sampled, together with the thoroughness of its mixture, was an important contributing factor in some of the cases where varietal differences occurred.

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In spite of the erratic behavior mentioned, the correlation between pollen germination and amounts of normal pollen is high. In table 12, along with the germination percentages have been included the percentages of normal pollen, thus allowing a direct comparison of the two sets of figures for both years. The highly significant correlation coefficients both for 1941 ($r=0.845$, d. f.$=21$) and 1942 ($r=0.614$, d. f.$=16$) indicate common causative factors for pollen appearance and germination, and show that varieties that have high percentages of normal pollen tend to be relatively high in germination. The converse is also true. The germination counts, therefore, tend to substantiate further the observations previously made regarding parental relationships and subsequent effect on the pollen level of hybrids.

Germination counts were obtained on 10 varieties in both 1941 and 1942 (table 12). The significant correlation coefficient ($r=0.755$, d. f.$=8$) indicates a fairly strong tendency for the percentage of germination from a given variety to be consistent from year to year.

TABLE 12.—*Pollen germination in 1941 and 1942: Comparison between germination and pollen normality in each year and of germination in the different years* [1]

Variety	Location of trees sampled [2]	Pollen count			
		1941		1942	
		Germination	Apparently normal [3]	Germination	Apparently normal [3]
		Percent	*Percent*	*Percent*	*Percent*
Advance	*GH*	11.1	38.9		
America	*GH*	1.7	47.7		
Bartlett	*ESO*	48.9	80.2	22.0	83.4
Botan	*GH*	40.9	90.8		
Bruce	*ESO*	3.1	25.7	9.4	34.4
Bruce Jr	*ESO*	8.3	50.8		
Burbank	*ESO*			44.3	85.9
Cumberland	*GH*	69.8	81.1		
Do	*ESO*	54.6	80.9		
Eagle	*ESO*			4.9	84.8
Elephant Heart	*ESO*			20.2	87.6
Excelsior	*GH*	4.3	61.9	2.4	66.0
Golden Beauty	*GH*	47.8	75.2		
Gonzales	*GH*	9.0	43.3		
Kelsey	*ESO*	13.8	61.7		
Methley	*DHO*	21.2	64.9		
Do	*ESO*			11.0	49.5
Munson	*GH*	1.1	57.7		
Nona	*GH*	.1	36.2	0	49.0
Poole Pride	*GH*	34.7	86.2		
Do	*ESO*			36.4	82.6
Santa Rosa	*GH*	21.8	69.4		
Do	*DHO*	47.5	77.7		
Shiro	*ESO*			16.3	90.3
Six Weeks	*GH*	1.9	41.9		
Do	*ESO*			3.3	40.3
Surprise	*ESO*			47.6	67.3
Terrell	*GH*	22.5	57.9	3.0	72.3
Wickson	*ESO*	34.0	84.3	34.2	94.2
Wild Goose	*GH*	49.0	73.3		
Do	*ESO*			21.3	53.2
P. besseyi	*ESP*			64.7	89.2
P. carolinana	*ESP*			65.0	94.7
P. mexicana	*ESO*	73.8	95.8		
P. reverchonii	*ESP*			55.9	95.5

[1] Correlation between germination and apparent pollen normality 1941: $r=0.845^{**}$, degrees of freedom$=21$; 1942: $r=0.614^{**}$, degrees of freedom$=16$. Correlation between germination in 1941 and 1942: $r=0.755^{*}$, degrees of freedom$=8$.

[2] See footnote 3, table 1.

[3] Data taken from table 1.

**=Significant at the 1-percent level; *=significant at the 5-percent level.

From the standpoint of the breeder the fact that the correlation between normal pollen and pollen germination is not more nearly perfect may be important. For example, in 1941 Excelsior with 61.9 percent of apparently good pollen had a germination percentage of only 4.3, while Golden Beauty with 75.2 percent of normal pollen had a germination of 47.8 percent. While there are exceptions, in general the proportionate difference between amounts of normal pollen and germination on agar is much greater in the American-Japanese species hybrids than in the other varieties. On the other hand, there are marked differences among that group of hybrids. For instance, Bruce with apparently the least good pollen has a low germination rate, yet one that is much superior to that of Nona. Because of these discrepancies it is probable that the germination rate of cultured pollen may at times have greater value for the breeder than a knowledge of the abortion level, especially in certain groups of plums. The correlation between pollen appearance and germination, however, indicates the value to the breeder of the microscopic appearance of the pollen, and of rapidly counting and calculating the percentages of normal appearing pollen. A knowledge of the correlation between pollen germination on culture and on naturally growing stigmas—in other words between artificial germination and biological reactivity—would be very interesting and helpful. In the present work nothing has been done on this subject and apparently very little detailed information concerning it is available from any species.

The pollen germination counts may be considered on the basis of varietal derivation; that is, whether the variety traces to a single species or is an interspecific hybrid. A direct comparison between the two classes of derivatives may be made from data in table 13, together with reference to table 12 and to table 1 for the parentage of the different forms.

TABLE 13.—*Pollen germination of plum varieties, interspecific hybrids compared to varieties tracing to a single species*

Derivation	1941		1942	
	Forms studied	Average germination	Forms studied	Average germination
	Number	*Percent*	*Number*	*Percent*
Single species	8	44.6	8	42.5
Hybrid	13	12.7	9	11.3

The hybrids average approximately one-fourth the germination of the single species forms. The comparatively high germination values among the hybrids, in both years, were for Bartlett and Wickson. This corroborates the conclusion that the *P. salicina* × *P. simonii* cross is a highly congenial one. The other two highest hybrid figures in 1941 were for Methley and Terrell. The only other hybrid giving a reasonably high germination in 1942 was Shiro, a form having a high percentage of normal pollen. With the exception of Terrell, the American and Asiatic species single crosses are all comparatively low in germination. This would seem to substantiate the observations already made regarding the effect on pollen sterility of most crosses between American and Eastern Asiatic species.

Even though the germination tests were more limited, and also less consistent, than the checks on apparent pollen normality, they do substantiate, and hence lend weight to, the conclusions based on the abortion studies.

SUMMARY AND CONCLUSIONS

The percentages of normal pollen and also the pollen germination rates of several plum varieties have been investigated in three different seasons. The plums studied have included most of those commonly grown in the Southwest as well as many little grown varieties and a number of botanical species.

In 1940 the amounts of normal pollen were studied in 37, in 1941 in 59, and in 1942 in 23 plum varieties or *Prunus* species. Correlation coefficients indicate a strong tendency for the percentage of normal pollen in a given variety to be consistent from year to year. Other environmental factors, such as the location of trees from which pollen was secured, also had no significant effect, on the whole, on the percentage of normal pollen within a variety.

Several factors affecting adequacy of the pollen sample were investigated. Significant flower-to-flower variation, with respect to aborted pollen, was found to occur on the same tree of Surprise plum. This and sample checks on collections of pollen of different size show that if a relatively small tree or varietal sample is to prove reliable, it must be taken from a sufficiently large and well-mixed pollen collection. It has seemed safe to conclude that 1,000-grain samples from such collections are adequate for reliability. This was the size of sample used in most of the present work. The data show, however, that much larger samples from small collections of flowers exhibit significant variation.

Pollen of 21 varieties in 1941 and of 18 in 1942 were germinated on nutrient agar. There was a significant year-to-year correlation for germination of the pollen of varieties used both years. For all varieties studied the proportion of germinating pollen was lower than that of normal appearing pollen. When all varieties studied in a single year were considered together, however, there were highly significant correlations between percentages of normal pollen and actual germination in each year. Individual exceptions occurred. The germination tests in general substantiate the conclusions based on results of the abortion studies.

Both the germination and the abortion studies make it seem likely that the degree of hybridity is responsible for the general level of pollen sterility, and hence that this level is fundamentally determined by the genotype of the variety. Pollen sterility, therefore, is a character which in some cases may be used as an indication of species relationships in plums if employed judiciously and where species affinities are not too close.

A knowledge of the pollen condition of the possible male parents has practical advantages from the plant breeding standpoint when working with the genetically diverse group of plums adapted to Texas and adjacent areas. A character desired from a pollen parent, such as fruit size, quality, or productivity, may be quite similar in two or more varieties each of which is genetically compatible with the intended seed parent. Choice of the pollen parent on the basis of

percentages of good pollen produced—whether judged by germination or to a practicable extent by appearance—may mean the difference between success and failure in the important result of obtaining sufficient seedlings to offer favorable probabilities of securing the desired character combination. In cases of possible variety choice it will usually be more efficient, as might be expected, to select a single species derivative over a hybrid form as a pollen variety. There are exceptions to this general rule, especially in the case of the varieties Wickson, Bartlett, Shiro, Methley, and perhaps others.

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THE EFFECT OF ADDING BLACKSTRAP MOLASSES, POTASSIUM SALTS, SUCROSE, AND CORN SIRUP TO A LAMB-FATTENING RATION [1]

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INTRODUCTION

During periods of abnormally high feed prices, blackstrap molasses often competes with feed grains as a source of energy for fattening livestock. The feed industry uses various amounts of blackstrap molasses as an ingredient of many proprietary mixed feeds. Patterson and Outwater (*10*)[2] studied the use of blackstrap molasses in feeds for steers and found that it improved both digestion and palatability. Snell (*12*), on the other hand, used various levels of molasses in feeding steers and found no consistent alteration in the digestion of a common ration. Williams (*13*) found that molasses reduced the ability of the dairy cow to digest protein.

Lindsey and Smith (*8*), working with mature sheep, found that molasses hindered the digestion of all nutrients with which it was fed. Briggs and Heller (*2*) reported that fat digestion, in particular, was lowered when blackstrap molasses was added to a lamb-fattening ration of corn and alfalfa. The digestion coefficients of protein, crude fiber, and nitrogen-free extract were also lowered somewhat but not significantly. Mitchell, Hamilton, and Haines (*9*) reported that additions of glucose reduce the ability of calves and lambs to digest protein and fiber and to utilize the energy of the ration. Hamilton (*5*) confirmed these results in studies with lambs. In recent experiments to determine the utilization of urea in the ration of lambs, Johnson et al. (*7*) have again shown that corn molasses lowers the digestion of protein and fiber in the ration.

Two digestion trials were carried out to determine the effect of sugar and potassium salts from various sources on the utilization of a common lamb-fattening ration. In the first trial, molasses and sucrose were substituted for shelled corn in a basal ration of corn, cottonseed meal, and alfalfa hay. Potassium salts were merely added to the basal ration. The sucrose substitution and addition of potassium salts were made in such amounts as to furnish the sugar and potassium salt level of blackstrap molasses. In the second trial, corn sirup was used to replace the sugar content of the blackstrap molasses. The molasses was fed in the second trial at 10-percent and 25-percent levels to find whether there was a difference in the tolerance of the lambs for the product at the two levels.

[1] Received for publication September 24, 1942.
[2] Italic numbers in parentheses refer to Literature Cited, p. 366.

PROCEDURE

Eight wether lambs in each of 2 trials, or a total of 16 lambs, were used in the study. The grade Rambouillet lambs used in trial 1 represented 8 of the heaviest lambs received in a shipment of 130 feeder lambs from southwest Texas. The 8 thrifty lambs used in trial 2 were similar in breeding and origin, but represented the lighter end of a group of lambs grazed until early February on wheat pasture in Oklahoma. These lambs were purchased on the open market in Oklahoma City. Lambs in both groups weighed approximately 75 pounds each at the start of their trials, and all lambs gained during the experimental periods.

The lambs were confined in 5- by 4-foot pens during a 10-day preliminary feeding period and were then placed in false-bottom metabolism cages, similar to those described by Forbes (*3*), for 1 10-day collection period. The lambs made more rapid live-weight gain in the cages than during the preliminary periods when they were confined to the pens.

Each lamb was fed the daily rations given in table 1. The feeds were weighed on a scale sensitive to 0.1 gm. Each lamb was fed in an open bucket while in the preliminary pen, but in a specially constructed feeder while in the metabolism cage. Practically no feed was lost in either case. The lambs received one-half the daily ration at each feeding and were fed at approximately the same time each morning and evening.

TABLE 1.—*Quantitative composition of the daily rations used in digestion trials with lambs*

Ingredients	Ration of—							
	Trial 1				Trial 2			
	A	B	C	D	E	F	G	H
Alfalfa hay.....grams	454	454	454	454	454	454	454	454
Cottonseed meal.....do	40	40	40	40	44	44	44	44
Corn (yellow).....do	410	205	205	410	410	183	319.2	183
Blackstrap molasses.....do	.....	205	.....	.....	.....	227	90.8	.....
Sucrose.....do	.....	.....	90.5	.....	.....	.....	.....	.....
Corn sirup.....do	.....	.....	.....	.....	.....	.....	.....	150.6
Salt-mix solution..cubic centimeters	.....	.....	.....	200	.....	.....	.....	.....

The corn was fed as whole shelled corn and the cottonseed meal was of pebble-cake size. The alfalfa was ground in a hammermill and forced through a ¾-inch-mesh screen. Blackstrap molasses and the dextrose sirup were weighed, then mixed with water, and the solution was added to the feed. The salt solution fed in ration D was a previously prepared solution, 200 cc. of which carried the same amount of potassium as 205 gm. of blackstrap molasses. All rations that otherwise would have been dry were dampened at each feeding so that the lambs would not object to a change of rations.

It has previously been reported (*2*) that a large addition of blackstrap molasses to a lamb-fattening ration reduced the apparent protien-disgestion coefficient when the molasses replaced one-half the corn in a ration of alfalfa hay and corn. No protein supplements were used. In the first trial herein reported, 40 gm. of cottonseed meal was fed

daily to each lamb to prevent any depression of digestibility because of insufficient intake of protein. During the second trial, 44 gm. of cottonseed meal was fed each day. Armsby (*1*) has referred to a "depression of digestibility" in rations that contain an excess of carbohydrates as compared to protein.

The same shipment of molasses was used in both trials. Sugar determinations showed the product to contain 44.16 percent total sugar or 29.04 percent sucrose and 15.12 percent invert sugar. Ash analysis showed a calcium content of 0.06 percent and a potassium content of 2.5 percent. The sucrose used in ration C was cane sugar purchased at a local grocery store; it contained 0.12 percent free moisture. The corn sirup contained 19.7 percent water, 44.5 percent reducing sugars as dextrose (dry-substance basis), 30.0 percent nonreducing sugars (dextrin, etc.) commercial basis, and 0.2 percent ash.

According to Harkness (*5*), K_2O equivalent composes 35 percent of blackstrap molasses ash. Of this K_2O equivalent, 32 percent is in the form of K_2SO_4, 21.1 percent as KCl, and 3.1 percent as K_2CO_3+KOH. From these data it was calculated that each 100 pounds of the blackstrap molasses used in these studies contained 1.701 pounds of K_2SO_4, 0.956 pound of KCl, and 0.130 pound of K_2CO_3. These salts were dissolved in these proportions in hot water, diluted until 200 cc. contained the same amount of potassium salts as 205 gm. of molasses, stored in bottles, and measured before each feeding.

Feces collections were made each day at the same hour and each day's collection was dried separately for 24 hours over an electric heater. The collection was then weighed and sealed. At the close of the 10-day collection period the dried feces for each lamb were placed in a basket, thoroughly mixed, and sampled for analysis.

The chemical composition of the feeds fed in both trials is given in table 2. Each year the feeds used were products of the preceding growing season and seemed to be normal in all respects. Both the corn and alfalfa hay were No. 2 grade.

TABLE 2.—*Percentage composition of the common feeds used in digestion trials with lambs*

Feed	Water	Protein [1]	Fat	Crude fiber	Ash	Nitrogen-free extract
TRIAL 1, NOV. 11, 1941, TO FEB. 20, 1942						
Alfalfa hay	9.51	16.44	1.71	29.42	7.23	35.69
Corn	13.87	11.56	3.48	2.11	1.33	67.65
Blackstrap molasses	34.59	4.06			8.22	53.13
Cottonseed meal	9.53	43.62	6.97	9.52	8.38	19.98
TRIAL 2, MAR. 2 TO JUNE 1, 1942						
Alfalfa hay	10.35	15.44	2.74	29.10	7.74	34.63
Corn	13.94	10.28	2.85	2.01	1.50	69.42
Blackstrap molasses	34.59	4.06			8.22	53.13
Cottonseed meal	8.95	42.94	6.59	9.10	6.62	25.80

[1] N × 6.25.

PRESENTATION OF RESULTS

Each of the eight lambs used in trial 1 was fed the four rations designated in table 3 as A, B, C, and D, and each of the eight used in trial 2 was similarly fed the rations designated E, F, G, and H. The coefficients of apparent digestibility for the different rations are given in table 3.

TABLE 3.—*Apparent digestibility (percent) of lamb rations with and without blackstrap molasses, sucrose, and potassium salts (trial 1) and with and without corn sirup and with two levels of blackstrap molasses (trial 2)* [1]

TRIAL 1

Lamb No.	Protein digestion coefficient for ration—				Fat digestion coefficient for ration—				Crude fiber digestion coefficient for ration—				Nitrogen-free extract digestion coefficient for ration—			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
352	73.7	61.2	70.6	70.8	73.2	60.9	51.5	60.4	49.2	46.7	48.8	45.1	83.7	80.6	84.9	82.3
338	74.1	69.2	71.4	74.2	65.2	60.2	61.1	62.3	50.2	50.3	44.4	41.7	83.9	83.1	83.1	84.7
321	77.4	69.3	73.6	75.0	69.2	61.1	61.6	64.2	55.8	47.4	49.1	43.2	86.5	82.8	83.9	84.7
336	74.7	68.6	71.8	71.7	67.2	57.4	61.4	71.2	46.0	45.2	44.9	45.9	83.8	82.3	85.6	84.0
328	75.8	68.8	70.4	75.7	63.1	60.6	60.7	66.3	45.0	48.6	46.4	46.9	85.8	81.6	83.9	85.1
285	73.5	68.0	70.4	73.2	70.7	64.8	59.4	67.4	41.5	44.3	49.7	47.0	83.6	82.2	82.1	84.6
84	71.9	68.2	70.8	66.7	60.3	61.1	50.5	64.7	45.7	47.4	47.0	40.5	83.3	83.0	81.2	83.5
373	73.9	70.0	67.1	68.9	68.2	68.6	55.9	63.2	48.1	45.2	45.2	38.5	86.8	82.3	82.1	82.7
Average	74.4	67.9	70.8	72.0	67.1	61.8	57.8	65.0	47.7	46.9	46.9	43.6	84.7	82.2	83.3	83.9

TRIAL 2

	E	F	G	H	E	F	G	H	E	F	G	H	E	F	G	H
286	67.0	60.7	64.2	63.4	68.0	45.5	49.6	58.8	44.9	42.7	43.9	43.7	83.4	75.3	82.1	85.4
290	72.7	66.3	69.6	64.4	69.2	64.3	64.1	58.3	51.7	50.7	51.6	41.6	86.7	81.6	85.2	85.7
284	68.5	57.3	69.8	62.6	61.3	41.2	65.8	56.7	48.0	46.7	52.3	43.3	83.3	82.0	86.2	82.8
287	67.8	65.7	69.3	59.4	65.4	58.4	65.6	55.3	41.6	54.2	41.4	45.8	83.6	83.3	84.9	83.7
289	70.1	64.9	60.7	63.5	56.0	65.5	68.1	54.2	47.9	46.3	46.7	41.6	85.2	82.8	83.5	83.1
288 [2]	(67.5)	------	(65.3)	(62.8)	(63.2)	------	(59.7)	(54.1)	(48.4)	------	(42.2)	(39.2)	(82.3)	------	(82.7)	(84.3)
283	70.2	54.7	66.3	55.6	68.8	50.1	56.9	56.8	46.1	42.2	47.2	38.8	86.8	80.0	78.8	85.8
285	71.1	61.8	67.3	66.5	62.4	54.8	62.7	61.3	49.1	44.9	42.5	41.6	85.2	81.8	82.6	84.2
Average [2]	69.6	61.6	66.7	62.2	64.4	54.2	61.8	57.3	47.0	46.8	46.5	42.3	84.9	81.0	83.3	84.4

[1] Ration A (check ration) consisted of corn, cottonseed meal, alfalfa, B, corn, cottonseed meal, alfalfa, and molasses; C, corn, cottonseed meal, alfalfa, and sucrose, D, corn, cottonseed meal, alfalfa, and potassium salts; E (check ration), corn, cottonseed meal, and alfalfa; F, corn, cottonseed meal, alfalfa, and 25 percent molasses; G, corn; cottonseed meal, alfalfa, and 10 percent molasses; H, corn, cottonseed meal, alfalfa and corn sirup. (See table 1.)

[2] Lamb No. 288 refused the ration containing the heavy allowance of molasses. None of the coefficients for No. 288 were used in calculating averages or in making statistical analysis.

Table 4 summarizes the test for significance of the differences between means in the two trials, as determined by the method of Snedecor (*11*). A value of $P=0.05$ was considered as the level of significance and a value of $P=0.01$ or above was considered highly significant.

The calculations in the second trial were made on the basis of seven lambs only, since No. 288 refused the high-molasses ration on the second day in the metabolism cage (his bowels had become quite loose while he was still in the preliminary pen). This lamb had previously eaten the ration containing the low level of blackstrap molasses and corn sirup as well as the check ration (E). When returned to the check ration, he immediately began to eat again and his digestive disorders cleared up. Although excluded from the statistical analysis, the coefficients for No. 288 are shown in table 3 for comparison.

The droppings of all lambs that received the higher level of molasses were noticeably softer than those of the lambs that received the lower level or no molasses at all. Fecal samples from the lambs receiving corn sirup and from those receiving the high level of molasses were very similar in appearance. In the first trial, the molasses, potassium salts, and sucrose rations often resulted in droppings that lacked the characteristic form for lambs, but actual scouring did not occur.

TABLE 4.—*Summary of the test of significance for differences between means of average apparent digestion coefficients of the lamb rations* [1]

Rations compared	Trial 1				Rations compared	Trial 2			
	Protein	Fat	Fiber	Nitrogen-free extract		Protein	Fat	Fiber	Nitrogen-free extract
A and B	(**)	(*)	(†)	(**)	E and F	(**)	(**)	(†)	(**)
A and C	(**)	(**)	(†)	(*)	E and G	(†)	(†)	(†)	(†)
A and D	(†)	(†)	(*)	(†)	E and H	(**)	(*)	(*)	(†)
B and C	(*)	(†)	(†)	(†)	F and G	(*)	(*)	(†)	(†)
B and D	(**)	(†)	(†)	(*)	F and H	(†)	(†)	(*)	(**)
C and D	(†)	(**)	(†)	(†)	G and H	(*)	(†)	(*)	(†)

[1] *= $P \leq 0.05$, significant; **= $P \leq 0.01$, highly significant; †=not significant.

DISCUSSION OF RESULTS

Since the check rations (A and E) differed slightly, the data for the two experiments were treated separately in the statistical analysis.

EFFECT OF BLACKSTRAP MOLASSES, POTASSIUM SALTS, SUCROSE, AND CORN SIRUP ON PROTEIN DIGESTION

In the present trials, the depression of the digestibility of protein by an inclusion of blackstrap molasses was greater on the higher levels of protein feeding than on the lower protein rations previously reported (*2*). In trial 1, a substitution of 205 gm. of molasses in ration B for a like amount of corn in ration A lowered the coefficient of apparent digestibility of protein by 6.5 percent. The standard error of this difference is 1.21; the difference is highly significant. In trial 2, where molasses constituted 25 percent of ration F, the coefficient of apparent digestibility of the protein was 8.0 percent lower than that of the check ration (E). The standard error was 1.85, and the difference was highly significant.

In trial 1, rations B and C were alike in the intake of total sugar, but unlike in that ration C contained much more refined sugar. The sugar in ration C was all pure sucrose, and did not include the high concentration of salts contained in the molasses added to ration B. Comparing these two rations with the check ration (A), the difference between rations A and C in apparent digestibility of protein was 3.6 percent, and accordingly was highly significant. In addition to this decrease, ration B had a coefficient of apparent digestibility 2.9 percent lower than that of ration C, and this decrease was significant (5-percent point). It thus appears that, in a lamb ration, at least a portion of the depression in the digestibility of protein produced by a high molasses intake results from the high sugar level of the diet.

The intake of potassium salts in ration D was also found to interfere somewhat with the lambs' ability to digest the protein in the ration. An addition of the salt mix to a ration identical in all other respects with ration A lowered the digestion of protein by 2.4 percent, but the difference was not significant. Neither was the difference between rations D and C. The difference of 4.1 percent between rations D and B was highly significant.

These results indicate that the depression in digestion caused by large amounts of blackstrap molasses in a lamb ration is at least partly the result of the high mineral content and is not all due to heavy sugar intake. The gross difference of 6.5 percent in digestion of protein between rations A and B is almost equaled by the 3.6 percent decrease caused by substituting pure sucrose for corn in ration C plus the 2.4 percent decrease from the addition of the potassium salt mix to ration D.

In trial 2, a substitution of 150.6 gm. of the corn sirup furnished 112.2 gm. of sugar to ration H, and the 227.0 gm. of molasses in ration F supplied 110.2 gm. of sugar. The apparent digestibility of protein was similarly hindered in both rations when these amounts of sugar replaced the 227 gm. of corn in ration E. The difference in apparent digestibility between rations E and F was 8.0 percent, the standard error of the difference was 1.85, and the difference was highly significant. Likewise, the difference of 7.4 percent between rations E and H was highly significant. Although there were some slight differences between the rations in the two trials and the same lambs were not used, it appears safe to conclude that the lambs were better able to digest the protein from a ration high in sucrose than from one carrying a large proportion of refined corn sirup, rich in dextrose.

Since the results of trial 1 and those of previous work at this station (*2*) had indicated that molasses cannot be fed to lambs at high levels without interfering with the digestion of several other nutrients, ration G was used in the second trial to study the effect of a 10-percent level of molasses in the ration. When rations E and G are compared, differences in the average digestion coefficients for protein indicate that at the lower level of molasses feeding there was no significant alteration in the digestion of protein in a corn, alfalfa, and cottonseed-meal ration. Five of the seven lambs failed to show as high coefficients as when the molasses was omitted. There was a significant difference in the lambs' ability to digest the protein of ration G, containing 10 percent of molasses, and ration F, containing 25 percent. Further studies are in progress to determine the level at which black-

strap molasses can be fed to lambs without its interfering with the utilization of the other components of the ration.

EFFECT OF BLACKSTRAP MOLASSES, POTASSIUM SALTS, SUCROSE, AND CORN SIRUP ON FAT DIGESTION

It was previously reported (*2*) that an inclusion of blackstrap molasses in the lamb ration decidedly lowered the apparent digestion of fat, and the present studies confirm this conclusion. A comparison of rations A and B shows that, on the average, the substitution of 205 gm. of blackstrap molasses for the same amount of corn lowered the digestibility of the fat 5.3 percent; the standard error was 1.95 and the difference was significant. A concentration of sugar in the diet in the form of commercial sucrose (ration C) equivalent to that supplied by the molasses in ration B, reduced the efficiency of fat digestion a total of 9.3 percent between rations A and C, a highly significant difference. A difference of 4.0 percent in the fat digestion of rations B and C was not significant.

Potassium salts lowered the average efficiency of the lambs in digesting fat, but the reaction of the lambs was neither consistent nor significant. Irwin, Weber, and Steenbock (*6*) have found that large amounts of calcium and potassium chlorides in the ration of rats decrease the digestion of fat.

In the second trial, the decrease of 10.2 percent between rations E and F in the average digestion coefficients for fat was highly significant. This is a greater difference than in the similar rations of the first experiment, but the amount of molasses in the ration was likewise greater. The 10-percent level of molasses fed in ration G did not depress the fat-digestion coefficient of the ration as much as did the 25-percent level of ration F. The substitution of the lower level of molasses for corn in ration G lowered the average coefficient for the seven lambs only 2.6 percent, which was not a significant difference. The difference of 7.6 percent between the two rations containing molasses was significant for the reduction between the two levels.

The addition of corn sirup to the ration at levels approximating a sugar intake comparable to that of the lambs on the molasses ration altered the average digestion coefficients of fat in the same direction but not to as great an extent. The average coefficient of 57.3 percent for ration H was 7.1 percent lower than that of ration E and the difference was significant. The other comparisons that might be made in average fat digestion were too small to be significant because of the large variation in the fat digestion coefficients within the rations.

EFFECT OF BLACKSTRAP MOLASSES, POTASSIUM SALTS, SUCROSE, AND CORN SIRUP ON CRUDE FIBER DIGESTION

In a previous paper (*2*) it was reported that blackstrap molasses added to a lamb-fattening ration lowered the digestibility of the crude fiber in the ration, but that the change was not significant. In both trials 1 and 2 it was again found that a reduction in the average digestion coefficients of crude fiber occurred when molasses was added to the ration; and in trial 1 sucrose brought about an average reduction identical with that of the molasses. There was very little difference in the results of feeding molasses at the two levels in trial 2. A significant reduction in the digestion of fiber occurred when the potassium salts were added to ration D and when corn sirup was used

to replace the corn in ration H. Furthermore, the addition of corn sirup lowered the fiber digestion significantly below that of the rations containing both levels of molasses. This latter observation confirms the report of Mitchell, Hamilton, and Haines (*9*), Johnson et al. (*7*), and Hamilton (*4*) that corn sirup markedly affects the ability of lambs to digest fiber.

EFFECT OF BLACKSTRAP MOLASSES, POTASSIUM SALTS, SUCROSE, AND CORN SIRUP ON NITROGEN-FREE EXTRACT DIGESTION

While the nature of nitrogen-free extract determinations makes their coefficients of digestion of questionable dependability, it is of interest to note that lambs do not digest the readily soluble sugars of molasses to as good advantage as might be expected. There was a 2.5 percent reduction in the coefficients of digestion between rations A and B and 3.9 percent between rations E and F. Both of these values are highly significant and are greater than have been reported in similar work (*2*). Sucrose lowered the nitrogen-free extract digestion coefficient a significant amount, while corn sirup and potassium salts had little effect. A 10-percent level of molasses lowered the average digestion of the soluble carbohydrates, but the alteration was not consistent.

The nitrogen-free extract from the ration containing corn sirup was digested on an average 3.4 percent more completely than that from the ration with the high concentration of blackstrap molasses. The difference was highly significant.

SUMMARY

In two digestion trials in each of which eight lambs were used, substitution of blackstrap molasses for at least one-half the corn in a lamb-fattening ration lowered the coefficients of apparant digestibility for protein, fat, and nitrogen-free extract an appreciable amount. Sucrose, used to replace molasses, reduced the digestion of each of these nutrients in the rations. The addition of corn sirup resulted in a lowered coefficient of digestion for protein, fat, and fiber, but did not particularly alter the digestion of nitrogen-free extract.

The addition of potassium salts to a ration lowered the utilization of all nutrients slightly, but only the apparent digestion of crude fiber was lowered a significant amount. Since the salts decreased the digestion of the ration less than blackstrap molasses, it appears that these salts can be only partly responsible for the general depression of digestibility resulting from the heavy feeding of molasses.

Limited work on the tolerance of lambs for blackstrap molasses indicates that lambs can utilize the product at a level of 10 percent of the ration more efficiently than at a level of 25 percent.

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